ATLAST Deployment &Push Pack Spares Optimizer

Presented by

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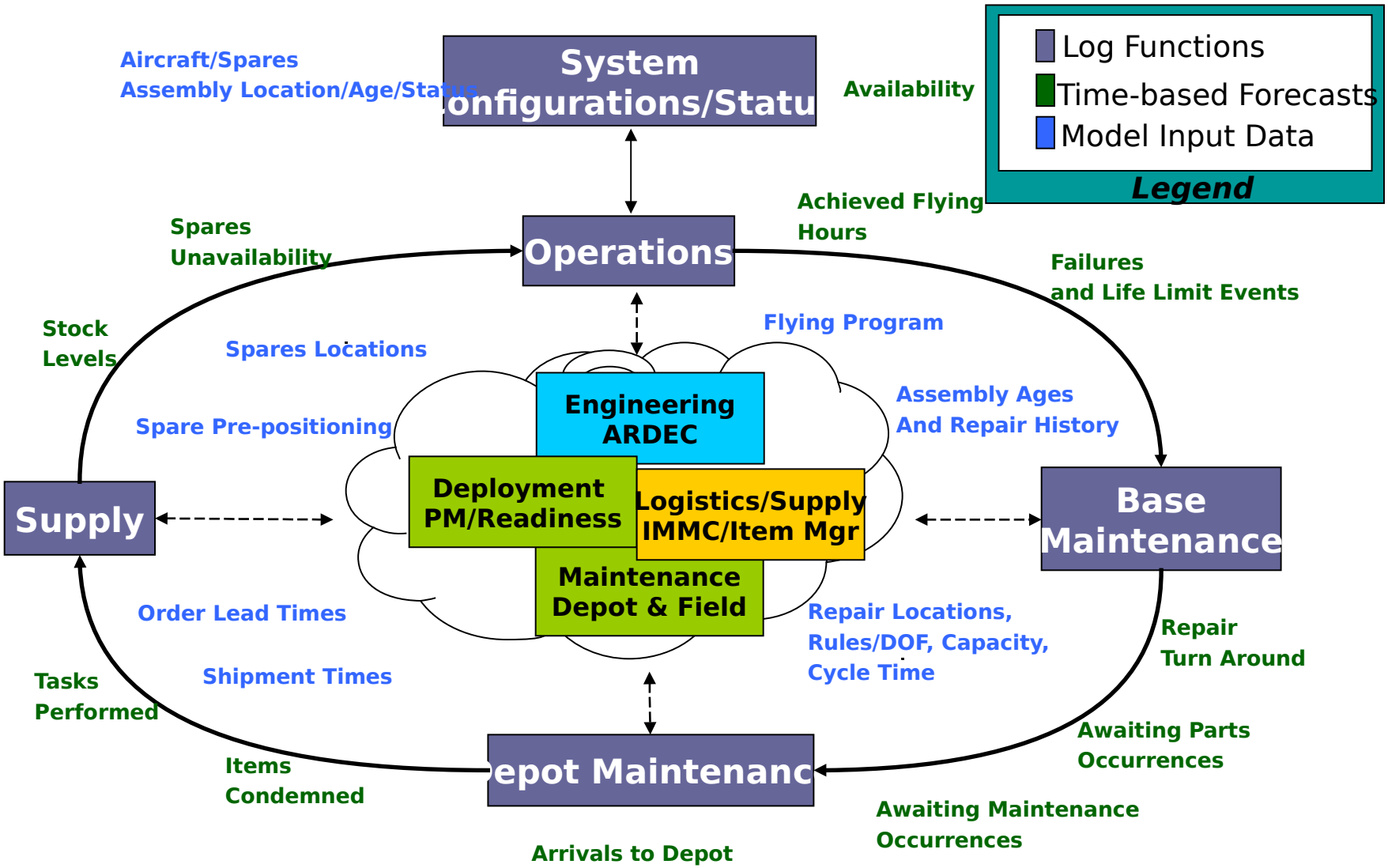
ATLAST Model Logic



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ATLAST Strengths & Applications

- **Real-World Complexities (State-based Forecasting)**
  - Supports Initialization Down to Serial Number
  - Initialized “State” of Components
  - Phased Aircraft Inductions by Tail Number
  - Aging Analysis
  - Recap, Zero Aging Analysis
  - Distribution Swapping based on Repair Count
  - Reconfigurable Indenture Structures
  - Life Limit Event Management
  - Op Temp Variations by Location
  - Interchangeability/Substitutability
  - Capacity Constraints
  - Time-Dependent Outputs

- **Analysis to be Supported with Model**
  - Maintenance Concept Modifications (e.g. Recapitalization)
  - Aircraft Induction Strategies
  - Operations Surge
  - Parts Purging
  - Sparing Strategies
  - Deployment Planning

ATLAST Outputs

- **Readiness**
  - Time on Wing
  - Availability
  - Achieved Flying Hours
  - Cumulative Age
- **Supply**
  - % of Time Awaiting Parts
  - Avg. Time Awaiting Parts
  - Spares Stock Levels
  - Spares Unavailability

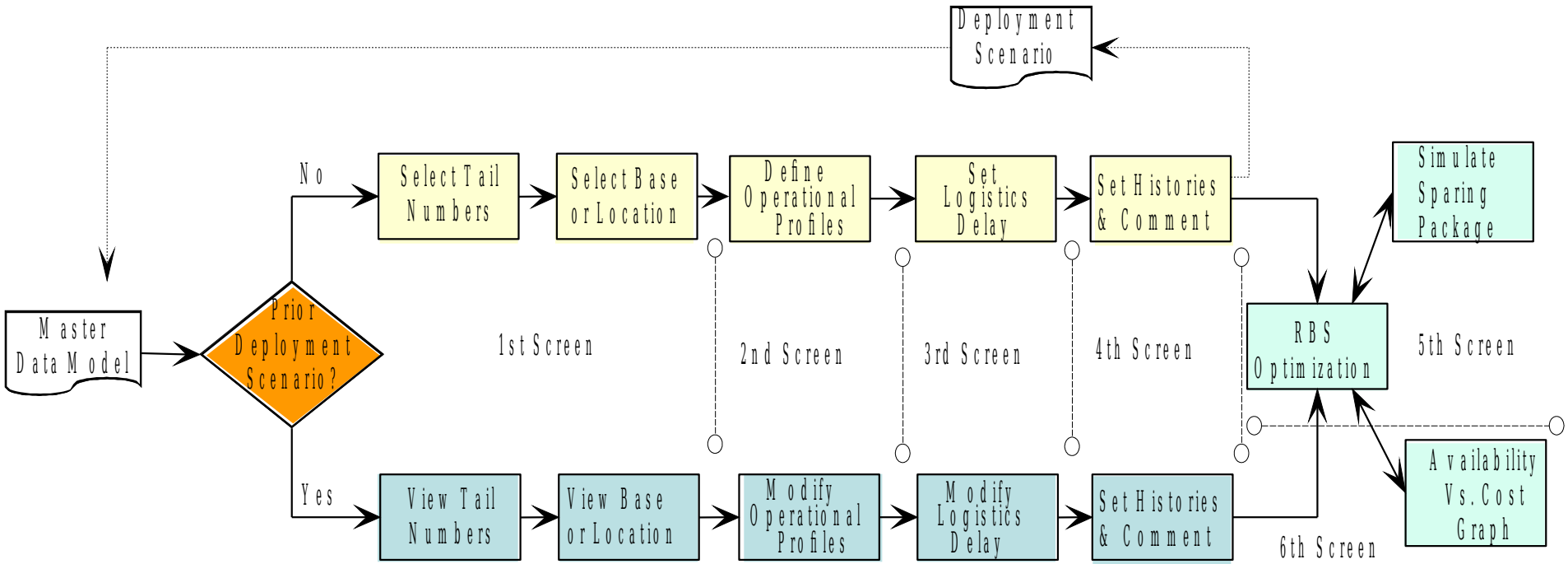
- **Maintenance**
  - Removals (Causal, Timed, Opportunistic)
  - Modules to Depot
  - Condemnations
  - Tasks Performed
  - % of Time Awaiting Maintenance
  - Avg. Time Awaiting Maintenance
- **Cost**
  - O&S
  - O&S Per Flight Hour

By Location and Time Dependent

ATLAST Optimizer

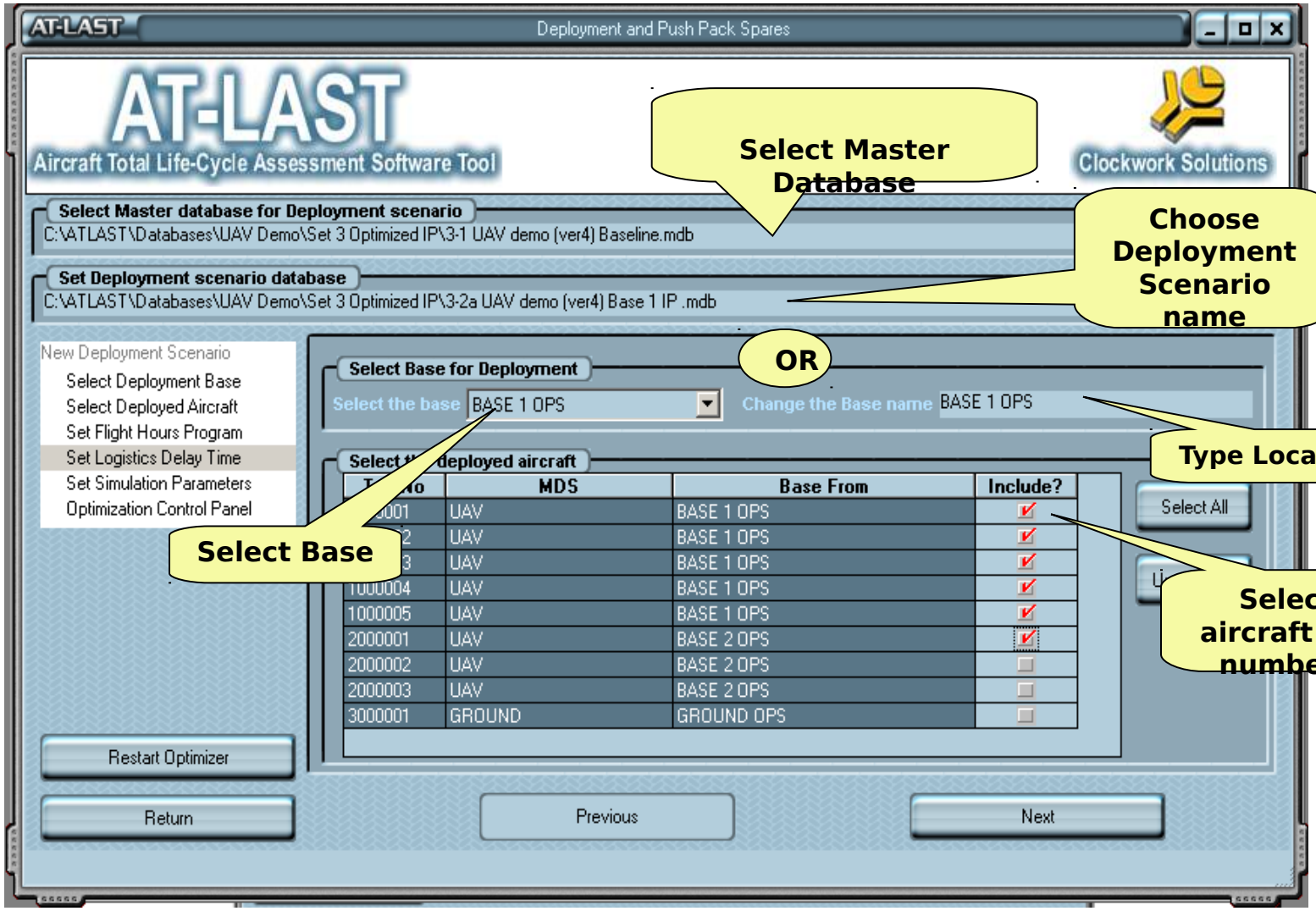
- Deployment & Push Pack Spares Optimization Module:
  - Creates a full deployment scenario on any number of aircraft at a single base
  - User defines logistics delay and operational profiles
  - Generates availability vs. cost graph
  - Provides analyst necessary information to determine optimal spares pack

Scenario Setup Process

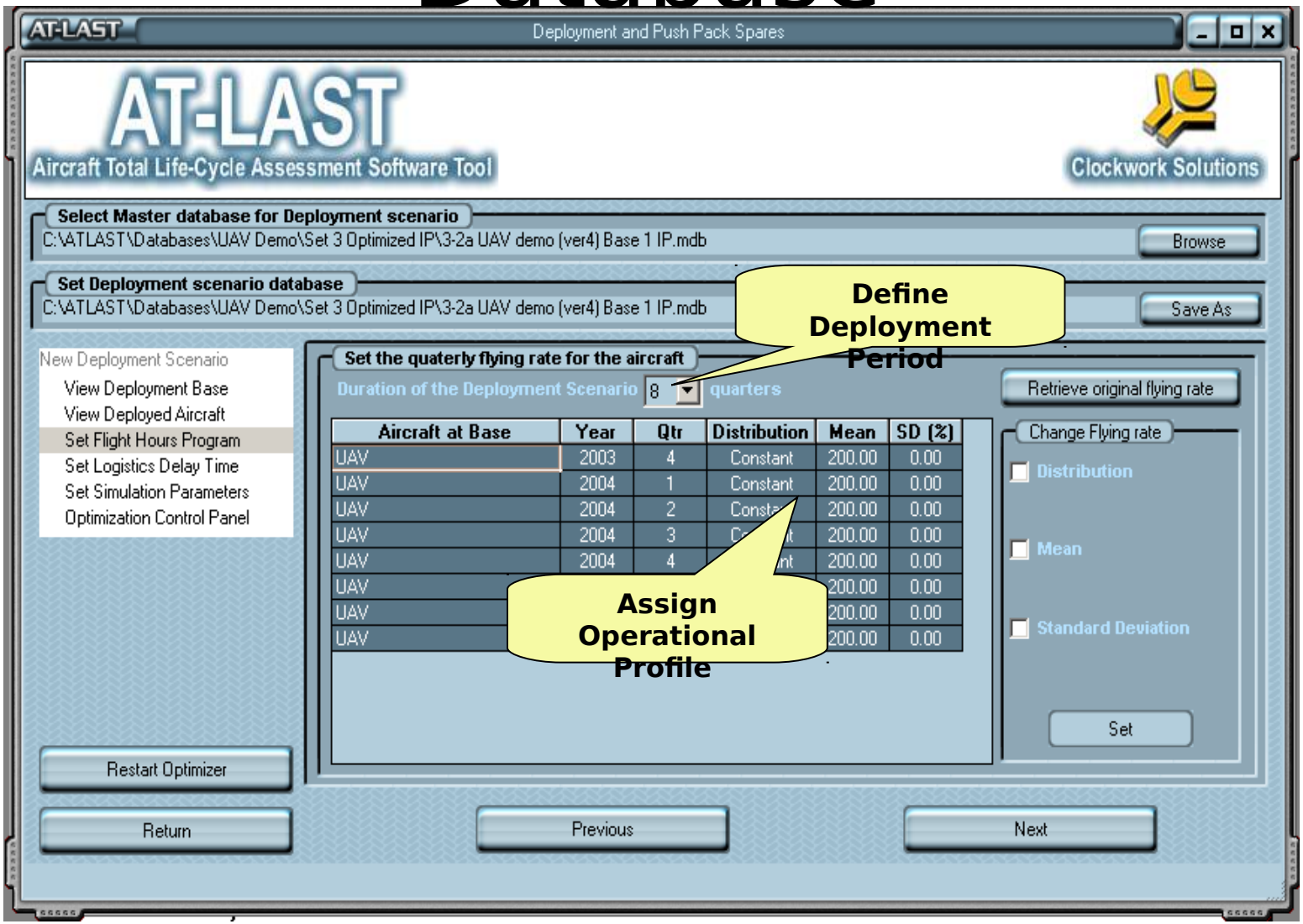


Scenario From Master Database

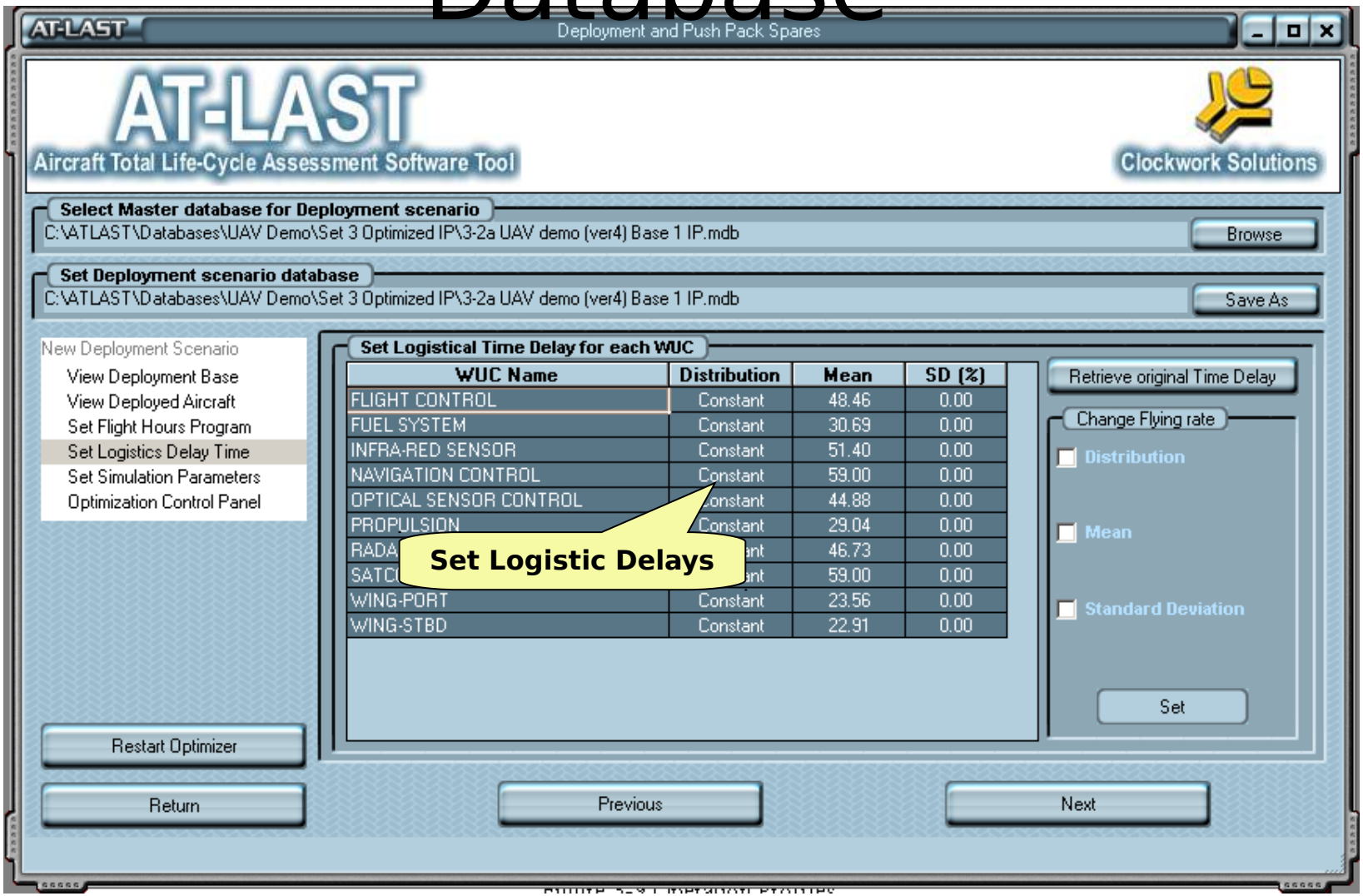
Choose Master



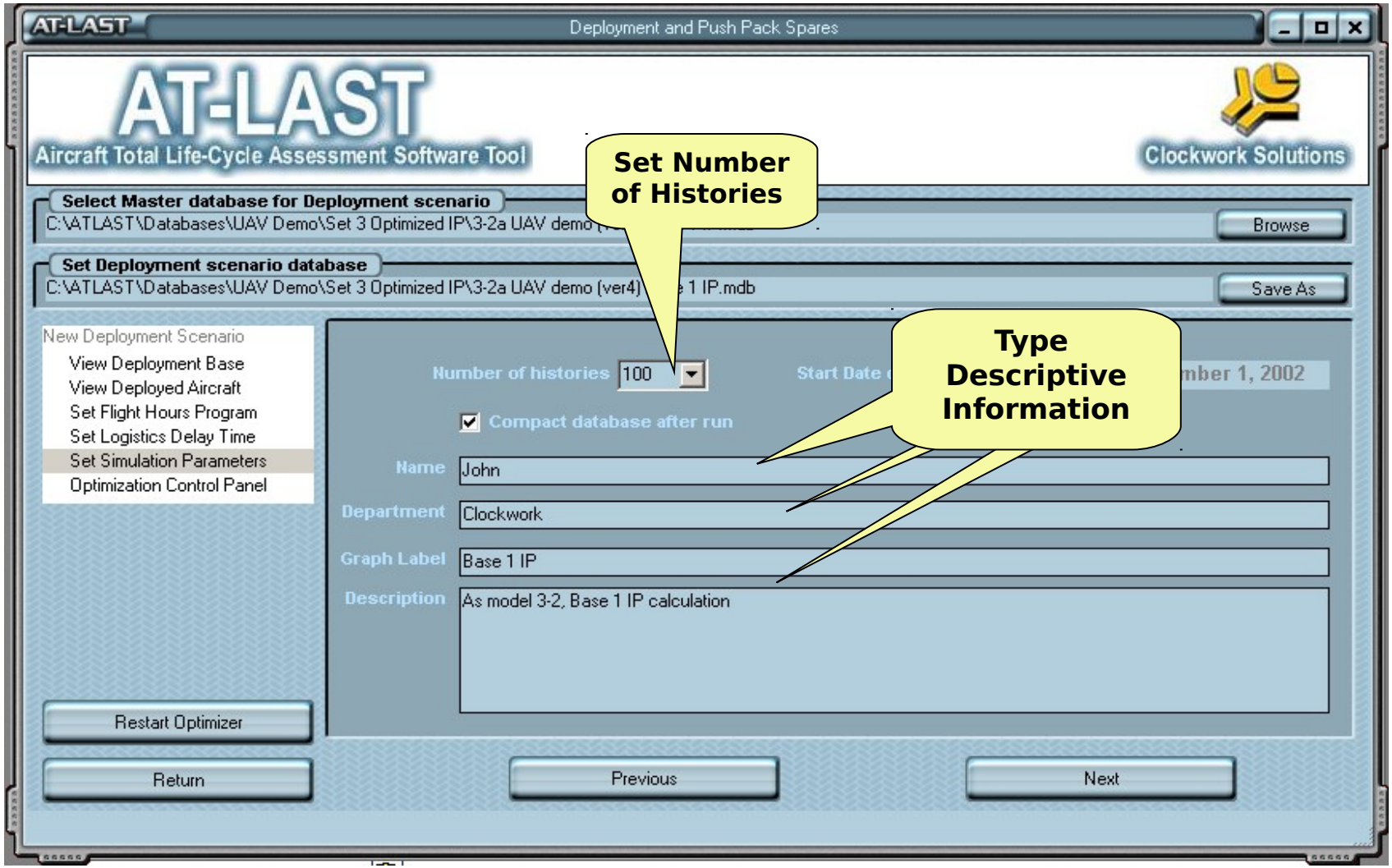
Scenario From Master Database


AT-LAST
Deployment and Push Pack Spares
AT-LAST
Aircraft Total Life-Cycle Assessment Software Tool
Clockwork Solutions
Select Master database for Deployment scenario
C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb
Browse
Set Deployment scenario database
C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb
Save As
Define Deployment Period
New Deployment Scenario
View Deployment Base
View Deployed Aircraft
Set Flight Hours Program
Set Logistics Delay Time
Set Simulation Parameters
Optimization Control Panel
Set the quaterly flying rate for the aircraft
Duration of the Deployment Scenario 8 quarters
Retrieve original flying rate
Aircraft at Base | Year | Qtr | Distribution | Mean | SD (%)
UAV | 2003 | 4 | Constant | 200.00 | 0.00
UAV | 2004 | 1 | Constant | 200.00 | 0.00
UAV | 2004 | 2 | Const | 200.00 | 0.00
UAV | 2004 | 3 | C t | 200.00 | 0.00
UAV | 2004 | 4 | nt | 200.00 | 0.00
UAV | 200.00 | 0.00
UAV | 200.00 | 0.00
UAV | 200.00 | 0.00
Assign Operational Profile
Change Flying rate
Distribution
Mean
Standard Deviation
Set
Restart Optimizer
Return
Previous
Next

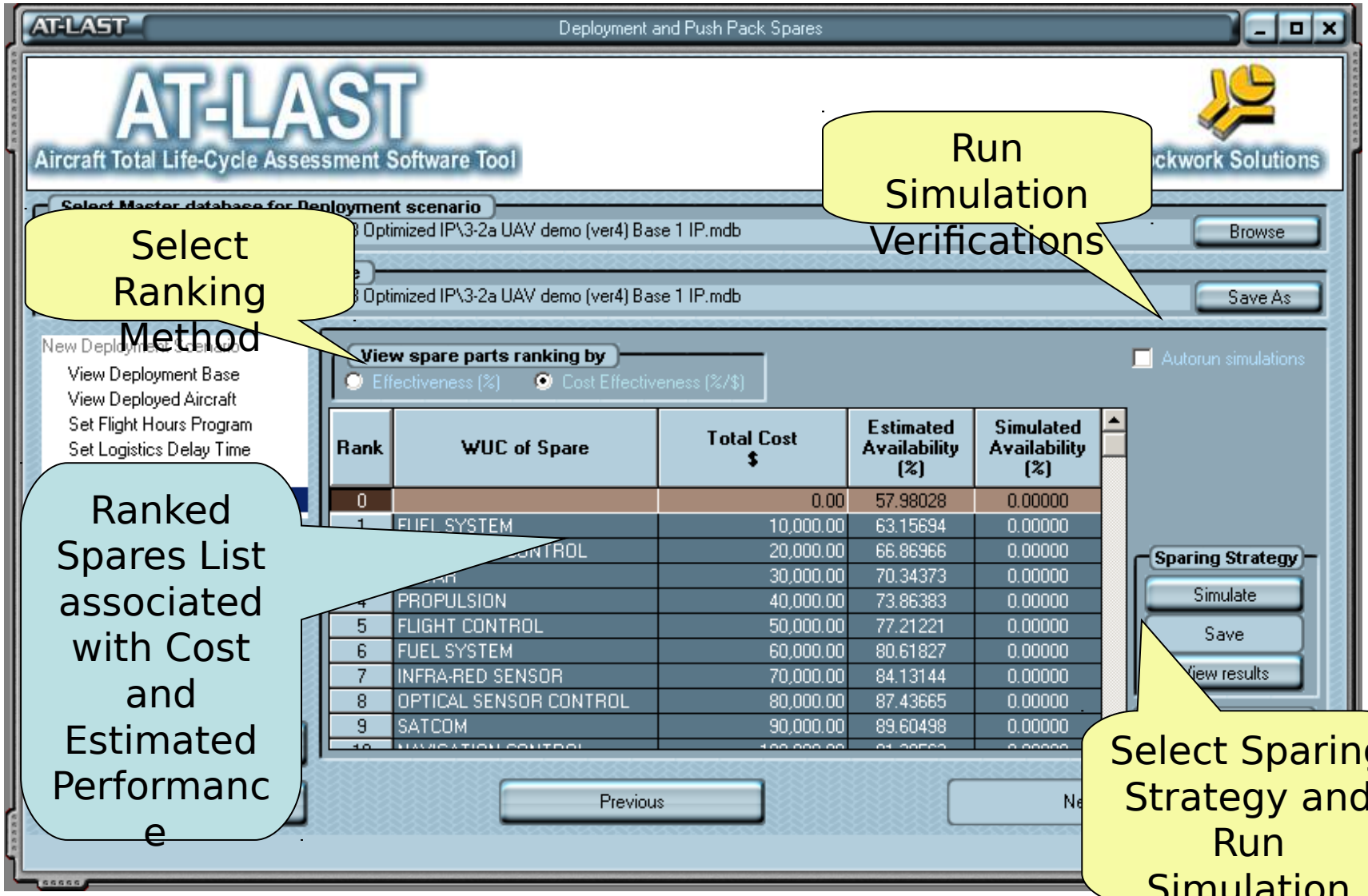
Scenario From Master Database



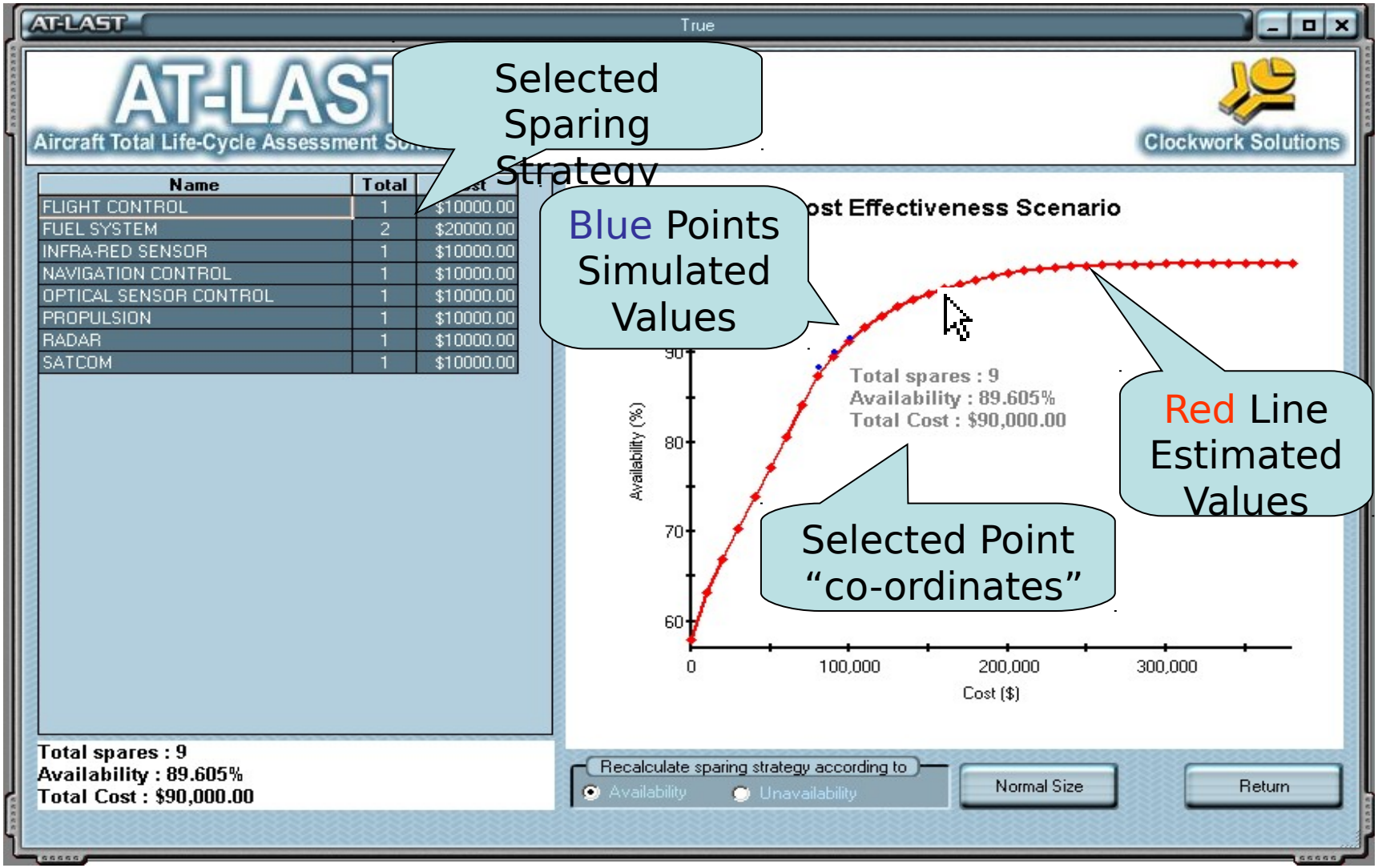
Scenario From Master Database



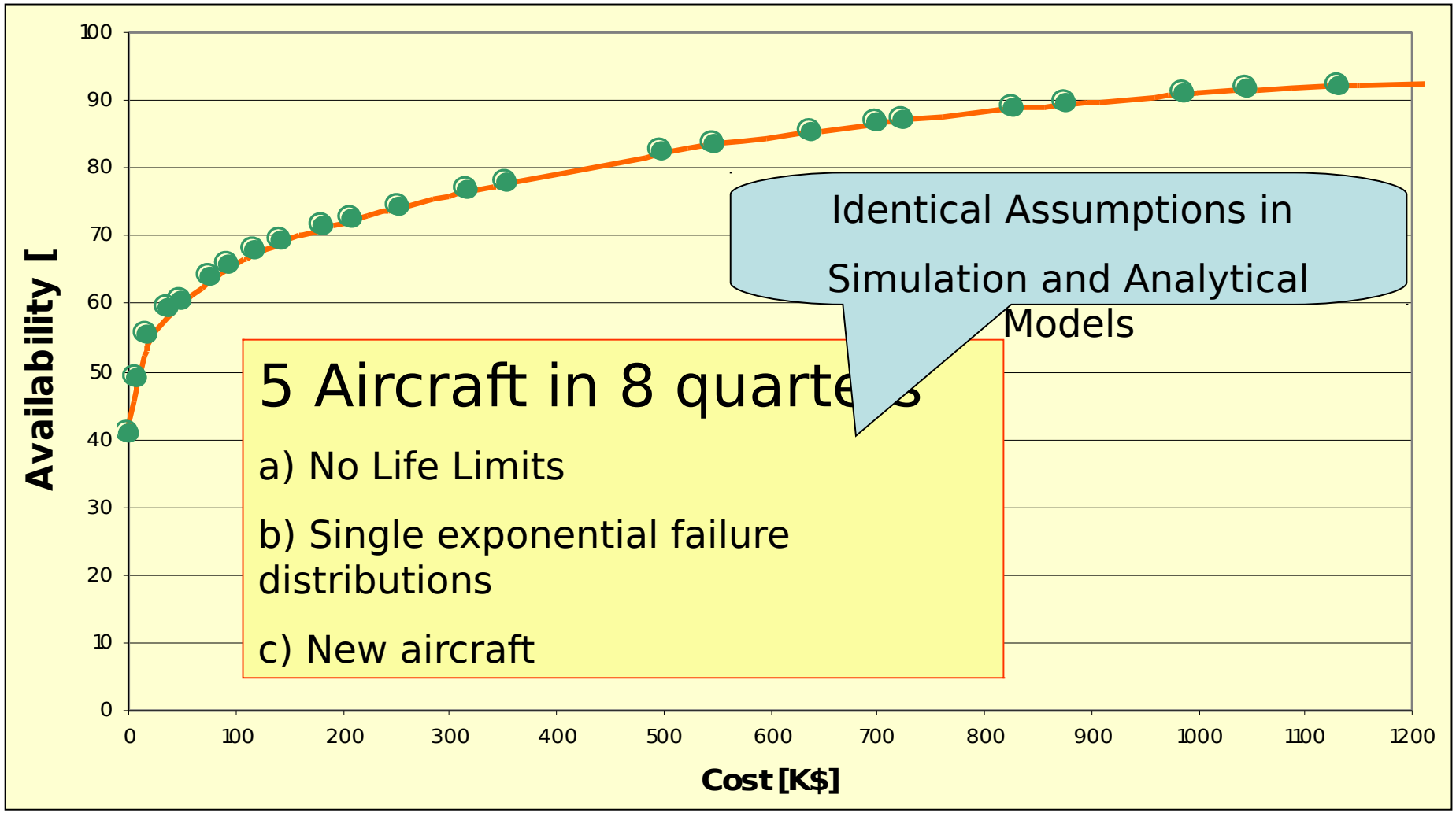
Simulation & Optimization



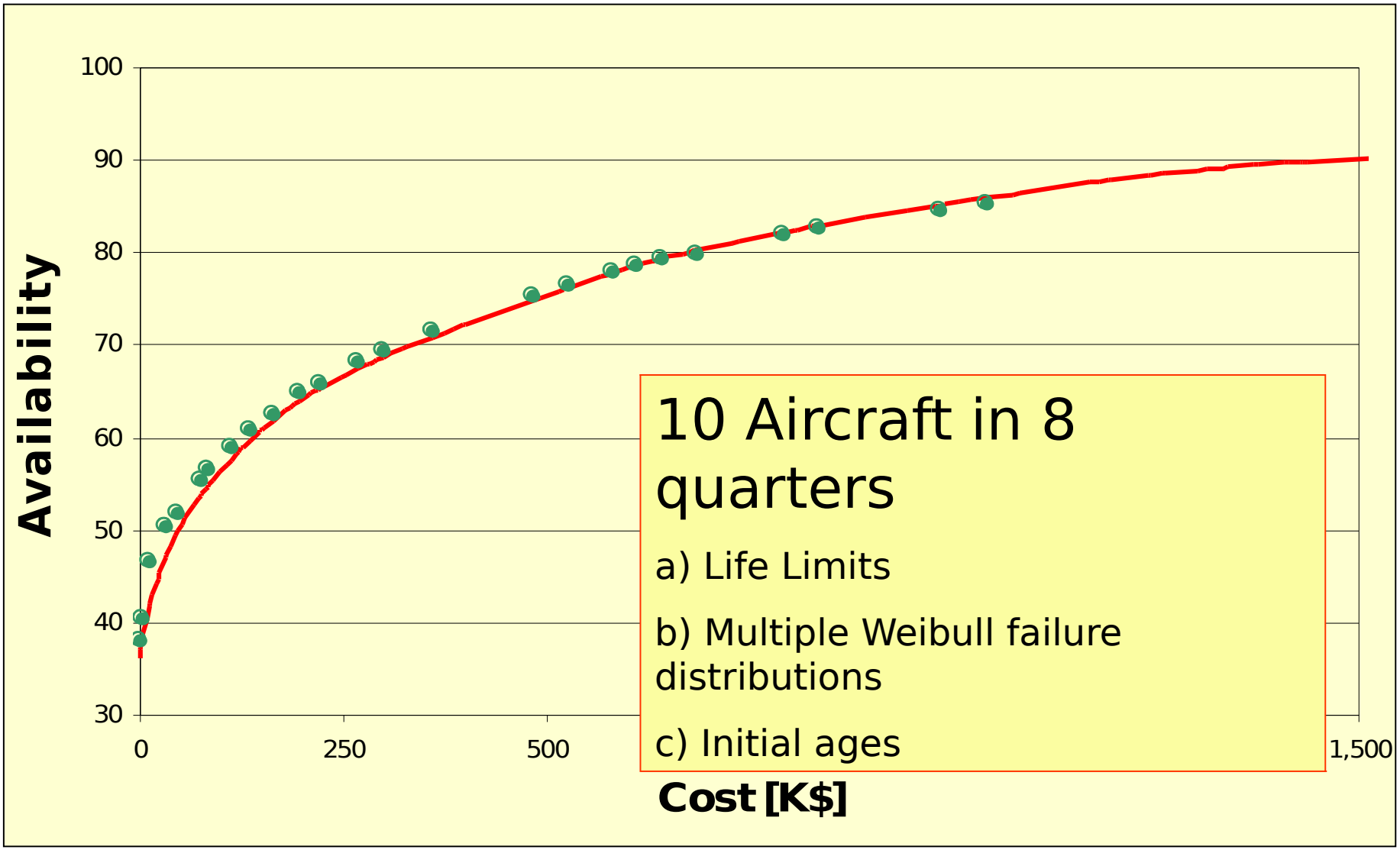
Simulation & Optimization



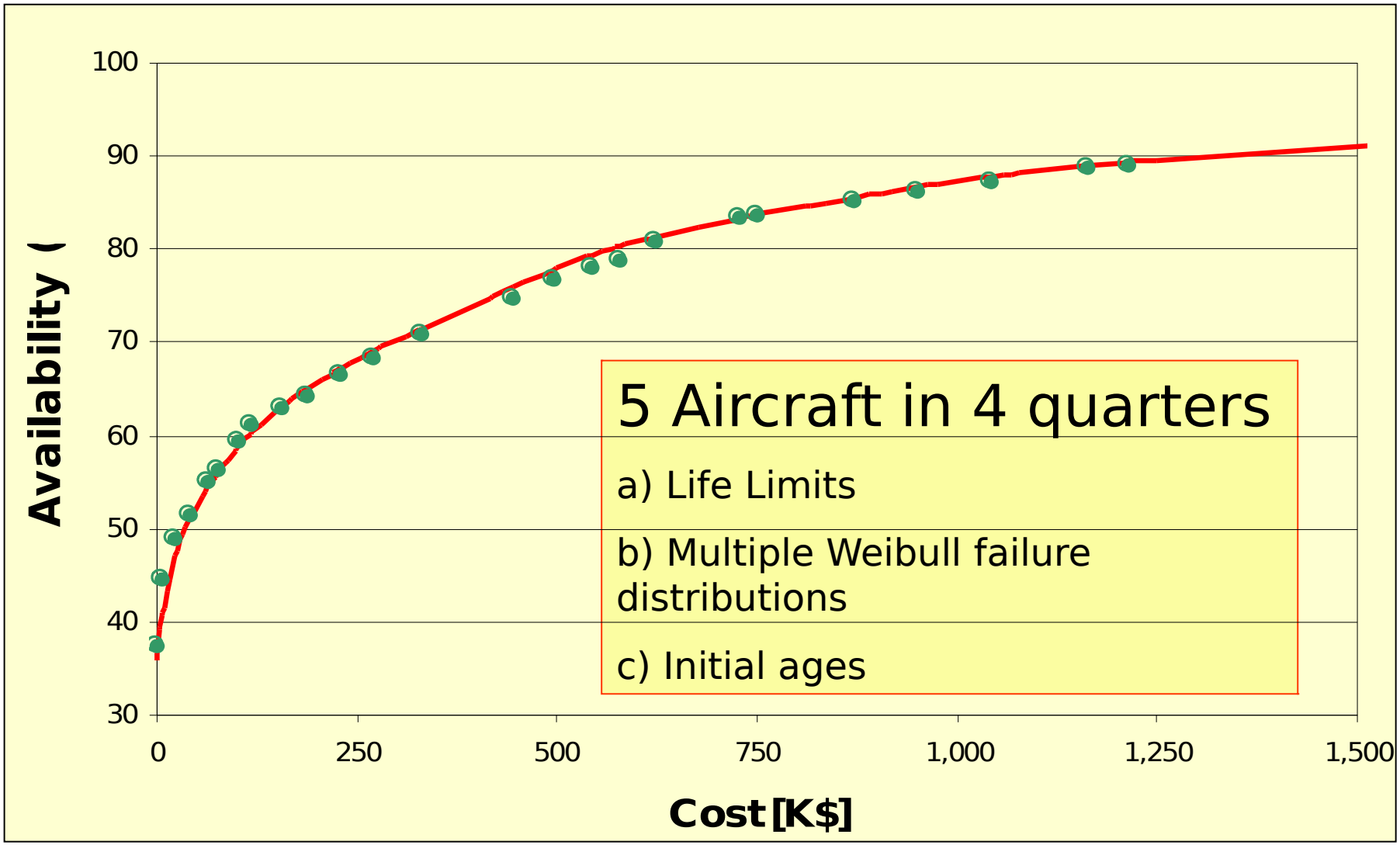
Validation


Availability [
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Cost [K$]
Identical Assumptions in Simulation and Analytical Models
5 Aircraft in 8 quarters
a) No Life Limits
b) Single exponential failure distributions
c) New aircraft

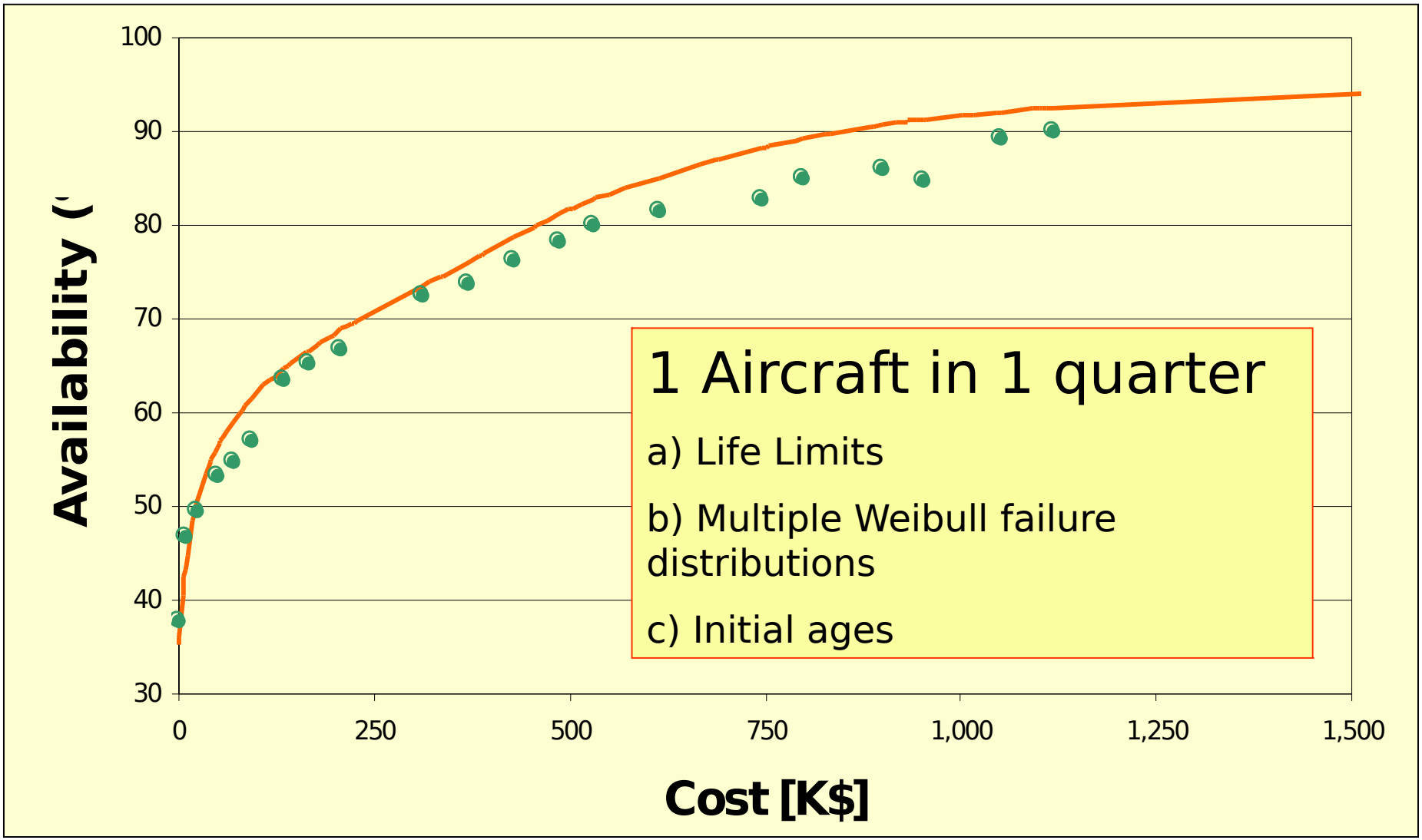
Numerical Results: Case A



Numerical Results: Case B



Numerical Results: Case C



Conclusions

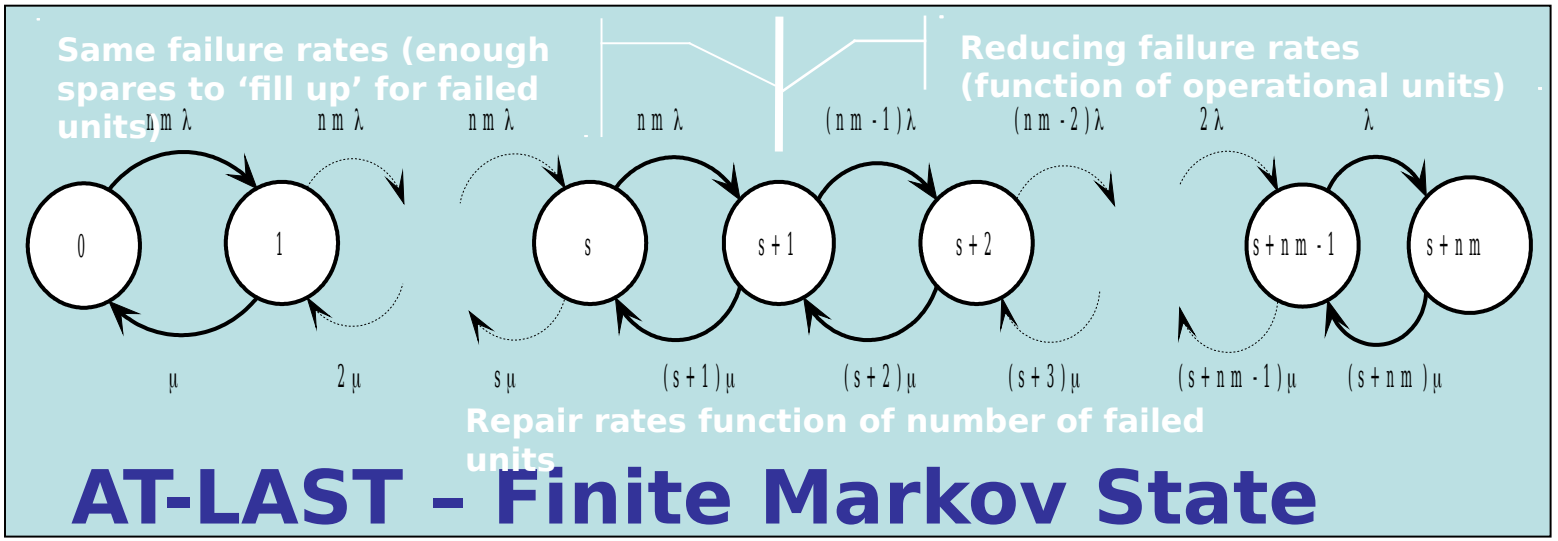
- AT LAST Deployment Push Pack Spares Optimization Module is both **accurate** and **efficient**
- Further developments will include:
  - An automatic adjustment mechanism
  - Improved handling of “coinciding” LRU removals occurrences
  - Importing optimization results to the master database

Thank You

Backup Slides

Mathematical Formulation

Markov Process States



AT-LAST – Finite Markov State Process

Legend

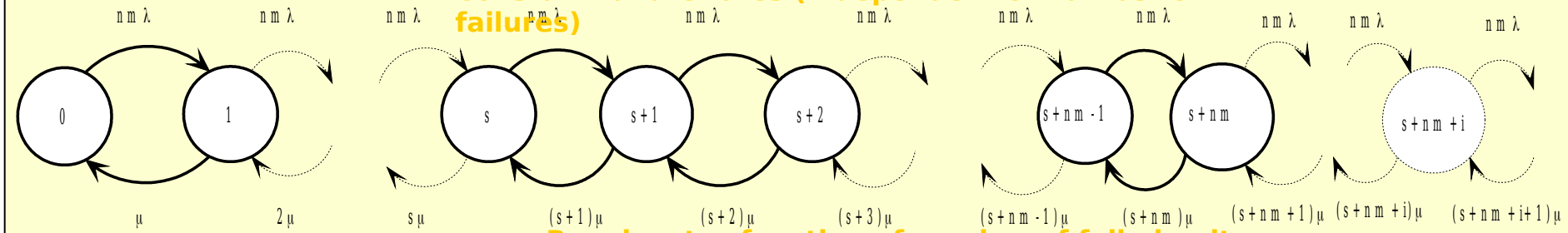
n=number of systems

m=number of LRU's per system

s= number of spares

λ= effective failure rate

μ= repair turnaround rate



Traditional – Infinite Markov State Process

Steady State Markov Equations

State 0 $0 = \mu P_1 - nm\lambda P_0$

$\vdots \qquad \vdots$

State s $0 = nm\lambda P_{s-1} + (s+1)\mu P_{s+1} - nm\lambda P_s - s\mu P_s$

State s+1 $0 = nm\lambda P_s + (s+2)\mu P_{s+2} - (nm-1)\lambda P_{s+1} - (s+1)\mu P_{s+1}$

$\vdots \qquad \vdots$

State s+n·m $0 = \lambda P_{s+nm-1} - (s+nm)\mu P_{s+nm}$

Boundary Condition $\sum_{i=0}^{s+nm} P_i = 1$

State 0 $0 = \mu P_1 - nm\lambda P_0$

$\vdots \qquad \vdots$

State s $0 = nm\lambda P_{s-1} + (s+1)\mu P_{s+1} - nm\lambda P_s - s\mu P_s$

$\vdots \qquad \vdots$

State s+n·m $0 = nm\lambda P_{s+nm-1} + (s+nm+1)\mu P_{s+nm+1} - nm\lambda P_{s+nm} - (s+nm)\mu P_{s+nm}$

$\vdots \qquad \vdots$

Boundary Condition $\sum_{i=0}^{\infty} P_i = 1$

Steady State Probabilities

$$P_i = \begin{cases} \frac{nm^i}{i!}\left(\frac{\lambda}{\mu}\right)^i P_0 & \text{if } 1 \le i \le s \\ \frac{nm^s s!}{(nm+s-i)!\,i!}\left(\frac{\lambda}{\mu}\right)^{i-s} \frac{nm^s}{s!}\left(\frac{\lambda}{\mu}\right)^s P_0 & \text{if } s \le i \le s+nm \end{cases}$$

$$P_o = \left[1 + \sum_{i=1}^{s} \frac{nm^i}{i!}\left(\frac{\lambda}{\mu}\right)^i + \frac{nm^s}{s!}\left(\frac{\lambda}{\mu}\right)^s \sum_{i=s+1}^{s+nm} \frac{nm^s s!}{(nm+s-i)!\,i!}\left(\frac{\lambda}{\mu}\right)^{i-s}\right]^{-1}$$

$$P_i = \left(\frac{nm\lambda}{\mu}\right)^i \frac{1}{i!} P_0 \quad \text{if } 1 \le i < \infty$$

$$P_0 = e^{-\frac{\lambda}{\mu}}$$

Poisson Distribution

Little Theorem $\lambda_\infty W = H$

$$W(s) = \frac{\frac{nm^s}{s!}(\lambda T)^s \cdot \sum_{i=s+1}^{s+nm} (i-s) \cdot \frac{nm^s s!}{(nm+s-i)!\,i!}(\lambda T)^{i-s}}{\lambda\left[\sum_{i=0}^{s} \frac{nm^{i+1}}{i!}(\lambda T)^i + \frac{nm^s}{s!}(\lambda T)^s \cdot \sum_{i=s+1}^{s+nm-1} \frac{nm^s s!}{(nm+s-i-1)!\,i!}(\lambda T)^{i-s}\right]}$$

Where: $T = \frac{1}{\mu}$ $\lambda = \frac{1}{MTTF + MTTR}$

$$W(s) = \frac{\sum_{i=s+1}^{\infty} (i-s) \cdot \frac{(nm\lambda T)^i e^{-nm\lambda T}}{i!}}{nm\lambda}$$

Where: $T = \frac{1}{\mu}$

Unavailability Estimates

ATLAST Expression: Applicable for serial systems in which LRU's do not fail while the system is down

$$U_{sys}(s_1,\ldots,s_L) = 1 - \frac{1}{1+\sum_{i=1}^{L} m_i \lambda_i (MTTR_i + W_i(s_i))}$$

Where: $\lambda_i = \frac{1}{MTTF_i}$ **calculated from outputs**